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Development of the lithium-ion cells for lunar exploration programs

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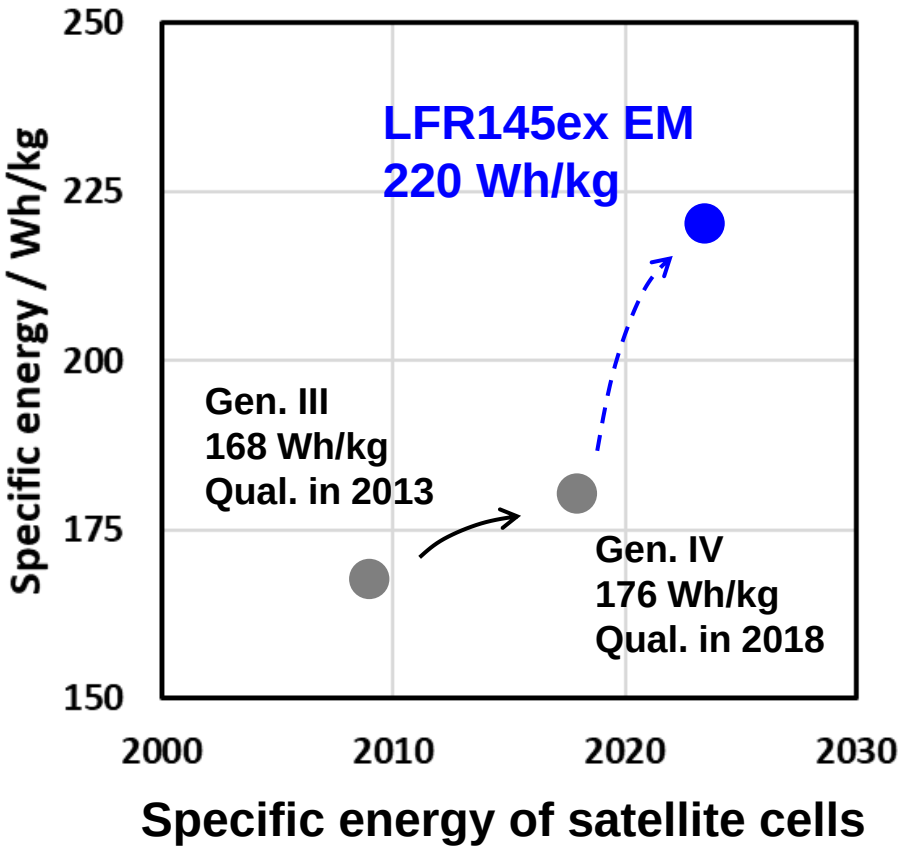
Background

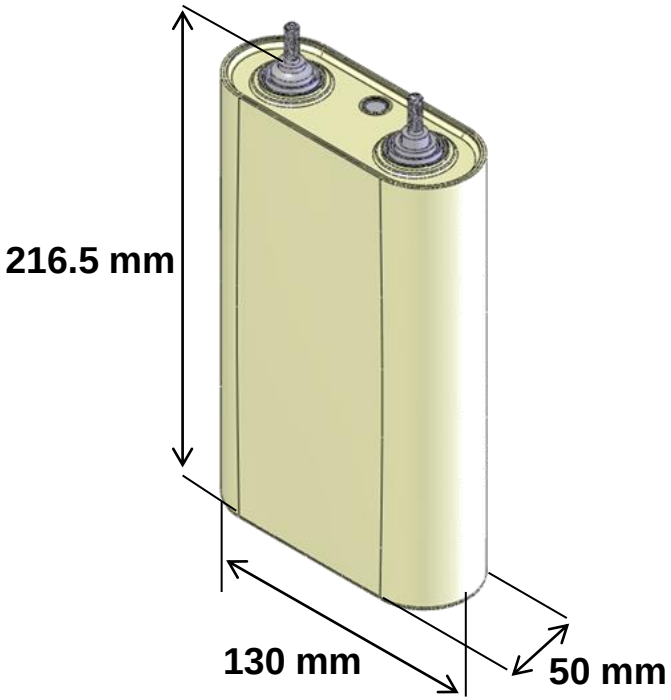
- ✓ **GYT developed the generation II, III and IV cells for satellite in cooperation with JAXA.**
  - **Gen. II : Qualified in 2008**
  - **Gen. III : Qualified in 2013**
  - **Gen. IV : Qualified in 2018**
- ✓ **The development of the lithium-ion cells for lunar exploration programs was also commissioned to GYT because these developments and superior flight performance to date have been highly evaluated by JAXA.**

Design concept

- ✓ **Increase the specific energy to 220 Wh/kg**
- ✓ **Superior cycle life performance at least up to 200 cycles to allow multiple overnights on the Moon**
- ✓ **Use the reliable heritage structure so that battery assemblers don't have to change their basic battery designs**



Target cell specification

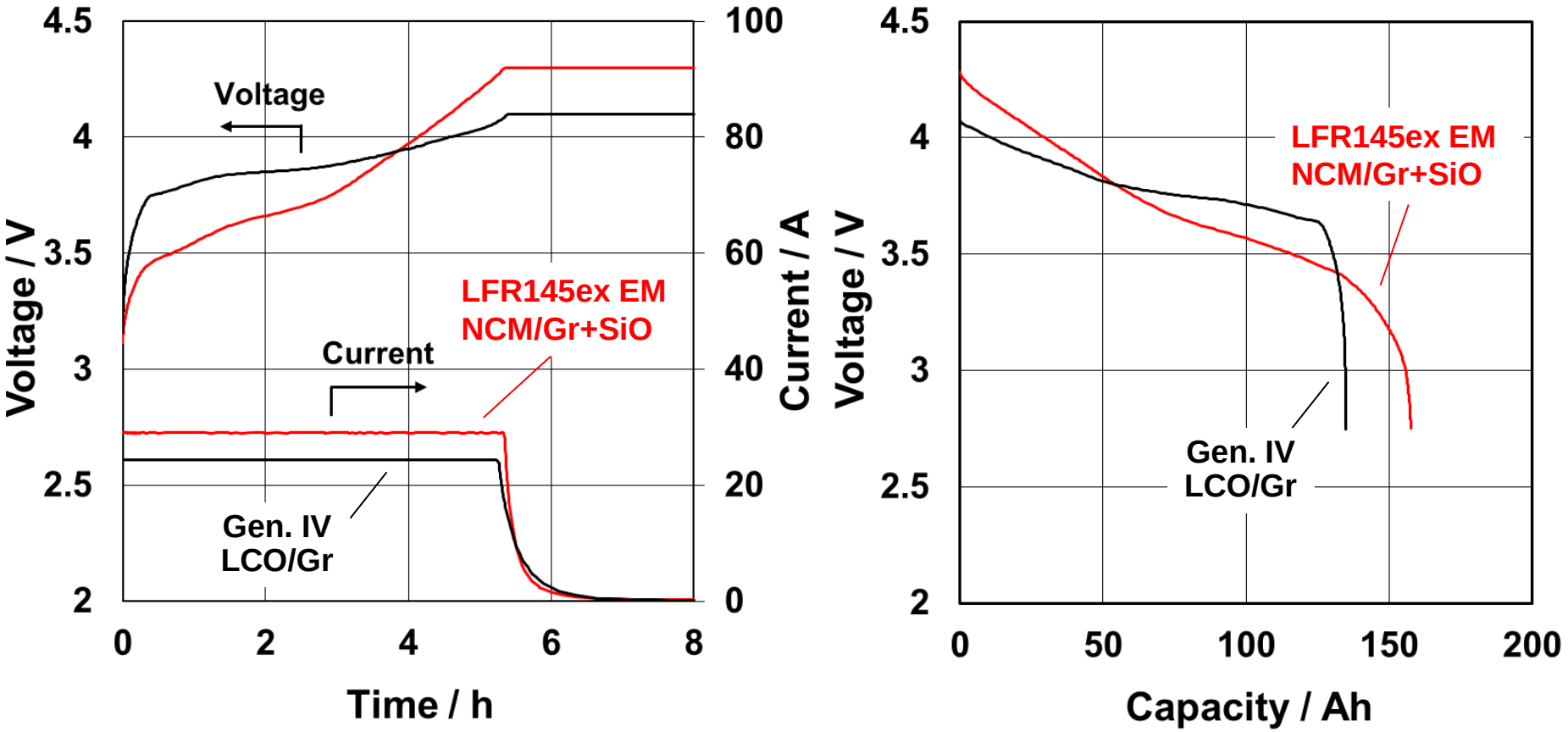


Appearance of LFR145ex EM cell
(Same size as 120 Ah cell)

Cell	LFR145ex EM	Generation IV (120 Ah)
Chemistry	NCM/Gr+SiO	LCO/Gr
Rated capacity / Ah	145	120
Actual capacity / Ah	160*	134
EoCV/ V	4.30	4.10
Discharge Voltage / V	3.69*	3.72
Mass / kg	2.69	2.83
Specific energy / Wh/kg	220*	165

*Discharge condition: 0.2 CA at 25°C

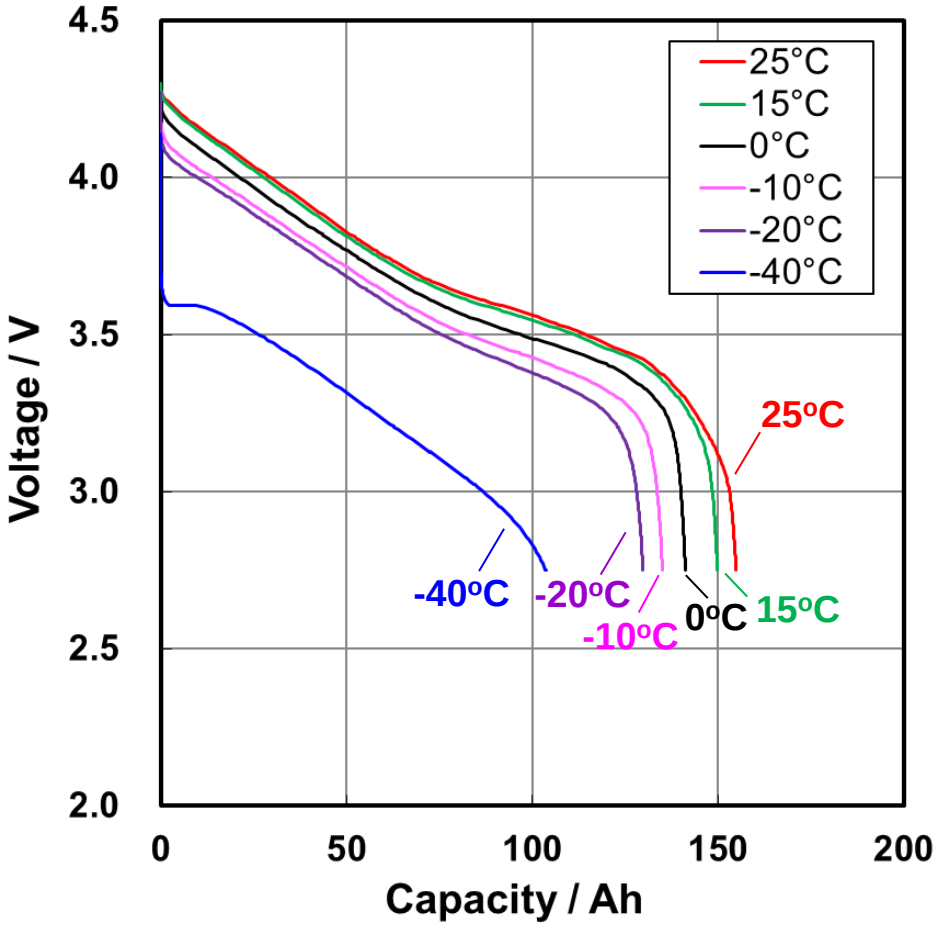
Charge and discharge characteristics



(a) Charge (b) Discharge

Representative charge and discharge performance of LFR145ex EM cell

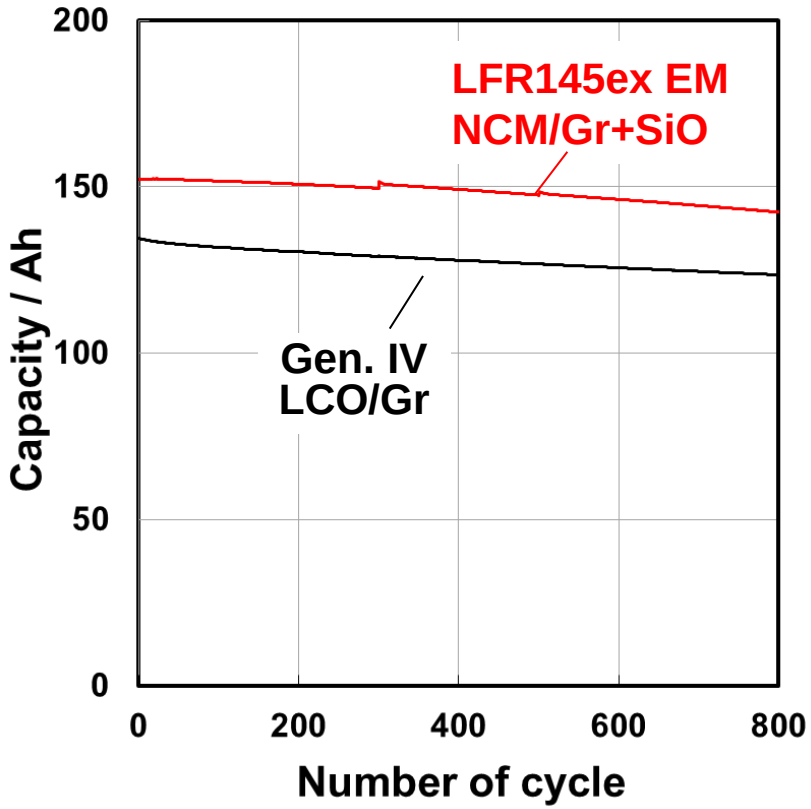
Effect of temperature



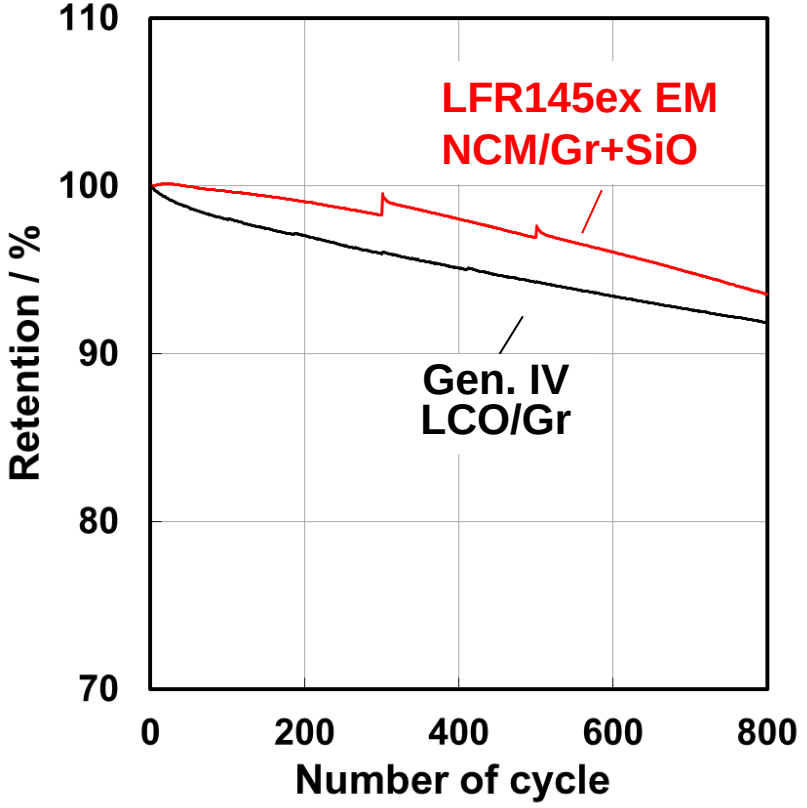
Discharge performance of LFR145ex EM cell at various temperatures

- ✓ **The cells demonstrated that it was able to discharge at extremely low temperature.**

Cycle life performance



(a) Capacity

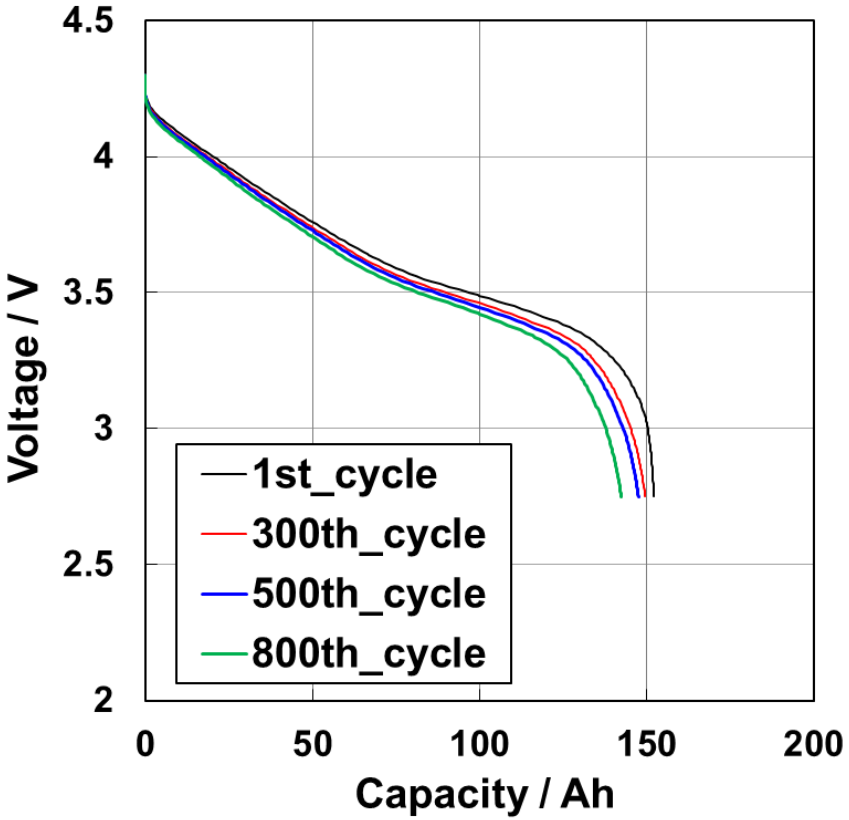


(b) Capacity retention

Cycle life performance of LFR145ex EM cells

- ✓ The cells demonstrated an excellent life performance to 800 cycles.
- ✓ This superior performance will enable the long-duration exploration on the Moon.

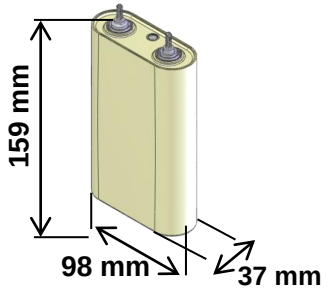
Cycle life performance



Changes in discharge performance of LFR145ex EM cells during 100% DOD cycle life test

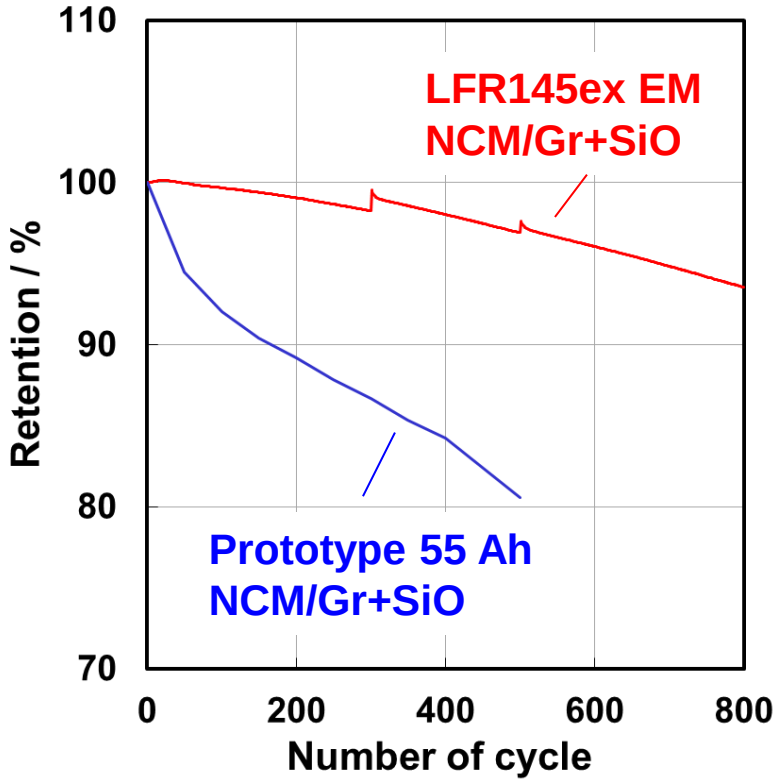
Operational simulation test (Reference)

✓ **Prototype 55 Ah cell has been subjected to the operational simulation test.**



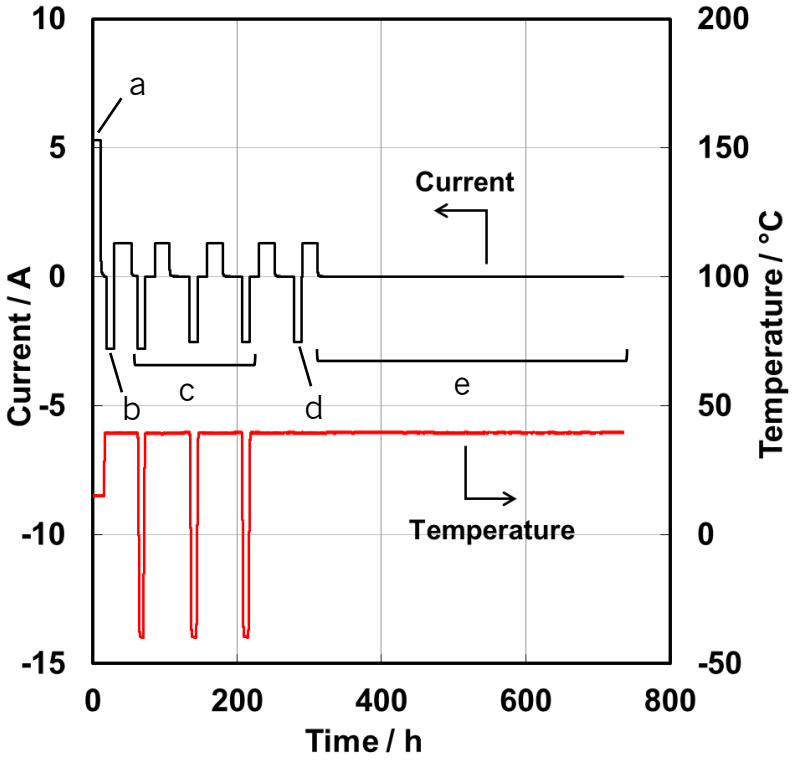
Appearance of prototype 55 Ah cell

Cell	Prototype 55 Ah
Chemistry	NCM/Gr+SiO
Rated capacity / Ah	55
Actual capacity / Ah	60
EoCV/ V	4.30
Discharge Voltage / V	3.69
Mass / kg	1.08
Specific energy / Wh/kg	208



Cycle life performance of prototype 55 Ah cell

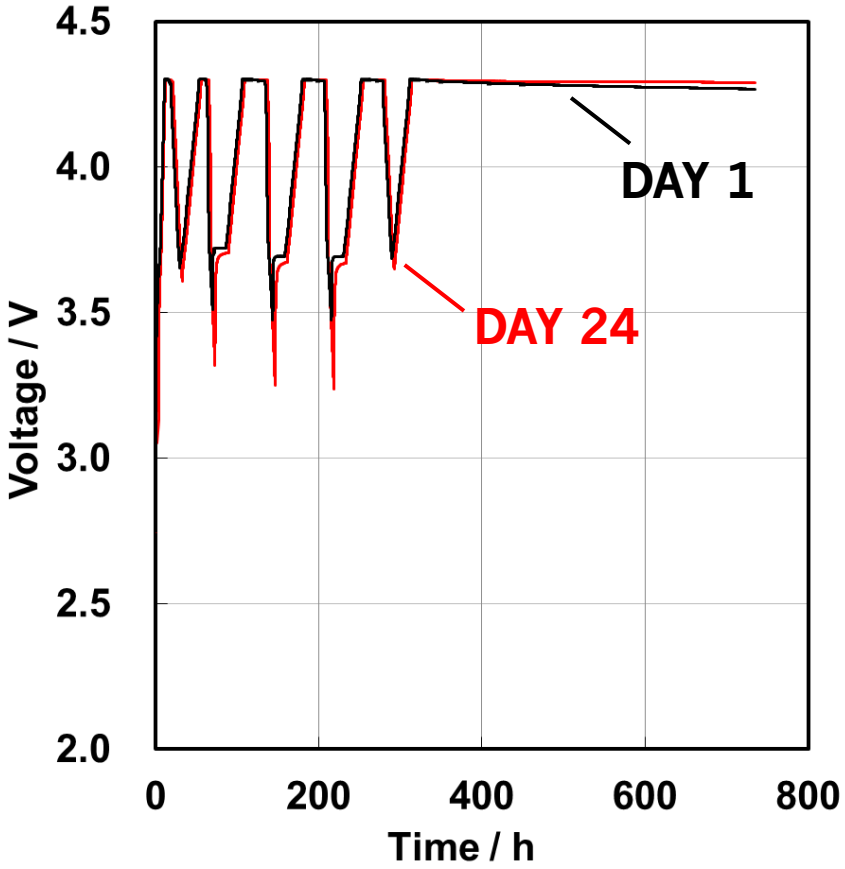
Operational simulation test (Reference)



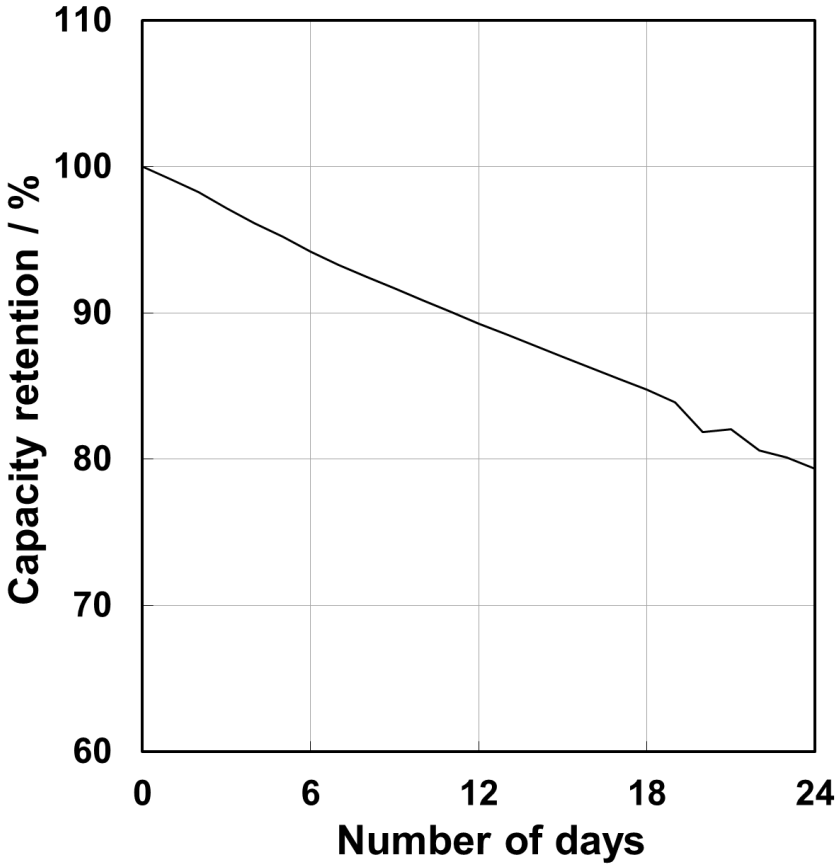
Temperature and current profiles of the one day on the Moon (1 set)

No.	Step	Temperature	Maximum DOD	Charge rate	Discharge rate
a	SOC adjustment	15°C	-	0.2 CA	-
b	Discharge in the sunshine area	40°C	60	0.025 CA	0.052 CA
c	Discharge in the shadow	-40°C	60	0.025 CA	0.048 CA ~0.052 CA
d	Discharge in the sunshine area	40°C	60	0.025 CA	0.048 CA
e	Waiting in the sunshine area	40°C	-	-	-

Operational simulation test (Reference)



Cell voltage profiles of DAY 1 and DAY 24



Full capacity change caused by operational simulation test

Environmental performance

Vibration test condition

(a) Sine

Frequency/ Hz	Level
5 to 27.9	6.4 mm (Single amplitude)
27.9 to 100	20 g

Sweep rate: 2 oct / minutes

(b) Random

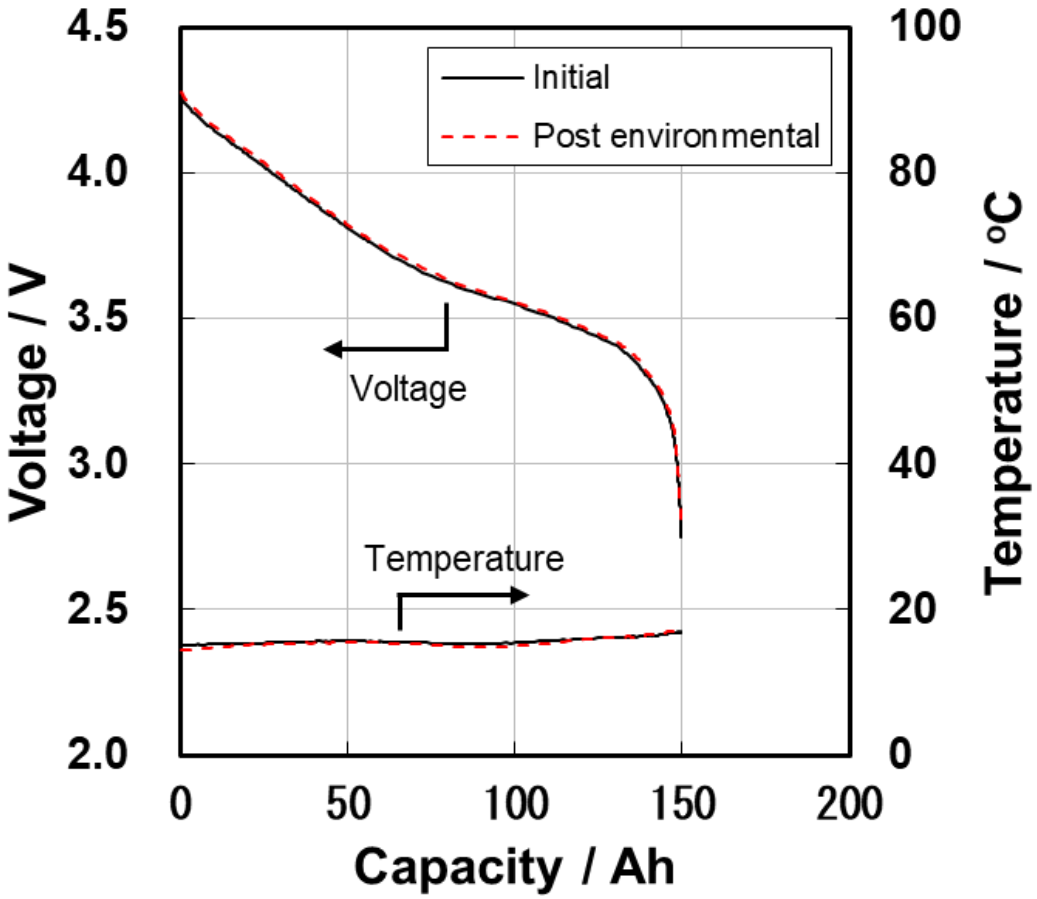
Frequency / Hz	Level	Grms
20 to 58	+6 dB/octave	23.63
58 to 700	0.5 g^2/Hz	
700 to 2000	-6 dB/octave	

Period: 3 minutes

Shock test condition

Frequency / Hz	Level
200	40 g
200 to 2000	+9.3 dB/octave
2000 to 7000	1400 g

Post environmental discharge performance



Post environmental discharge performance of LFR145ex EM cells

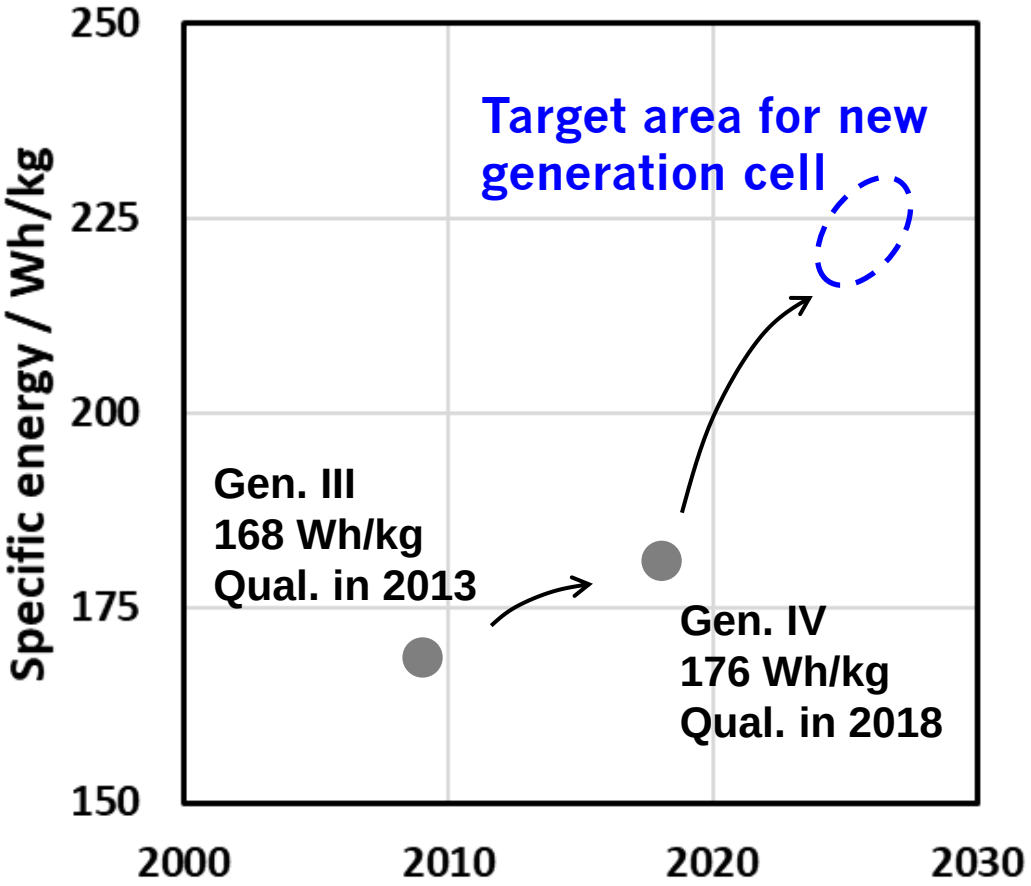
✓ **The cells passed all the environmental tests.**

Summary

- ✓ **LFR145ex EM cells have shown a specific energy of 220 Wh/kg by using the chemistry of NCM/Gr with SiO.**
- ✓ **In addition, it demonstrated an excellent life performance up to 800 cycles.**
- ✓ **The cells passed mechanical environmental tests.**
- ✓ **Cell qualification will be carried out based on the plan of JAXA's program.**

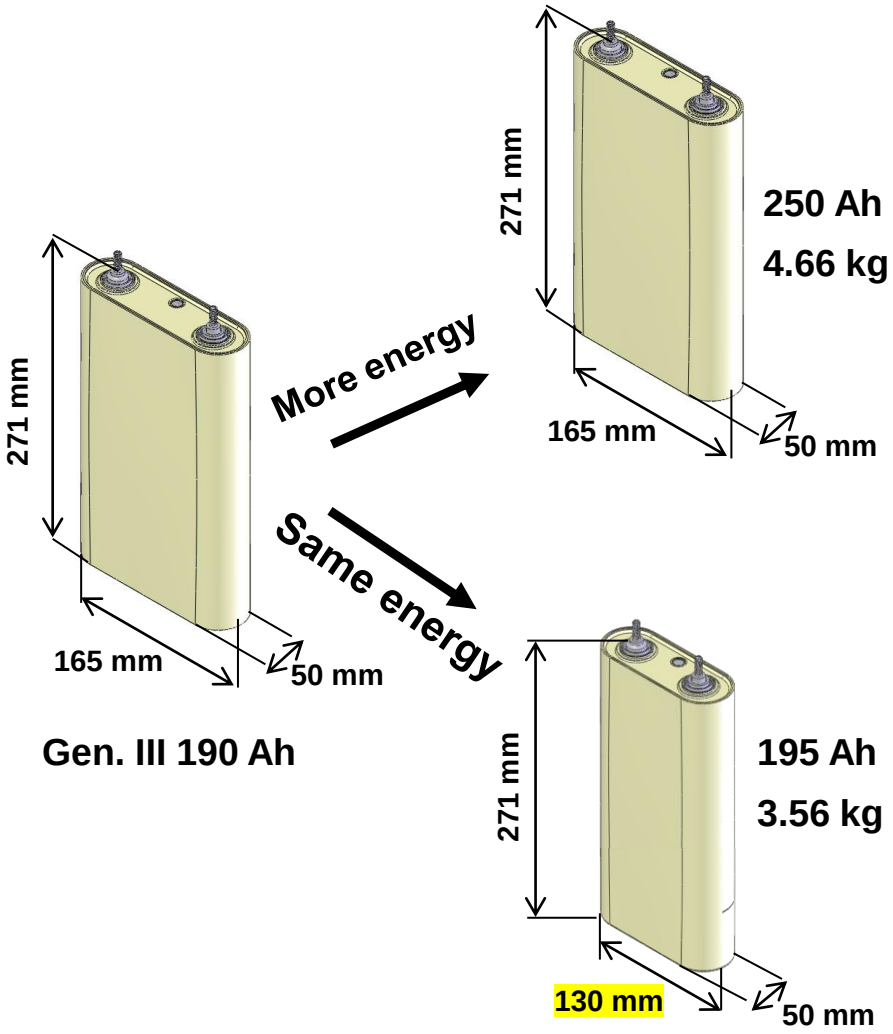
Development status of the new generation cells for satellite

Target Specifications of new generation cells



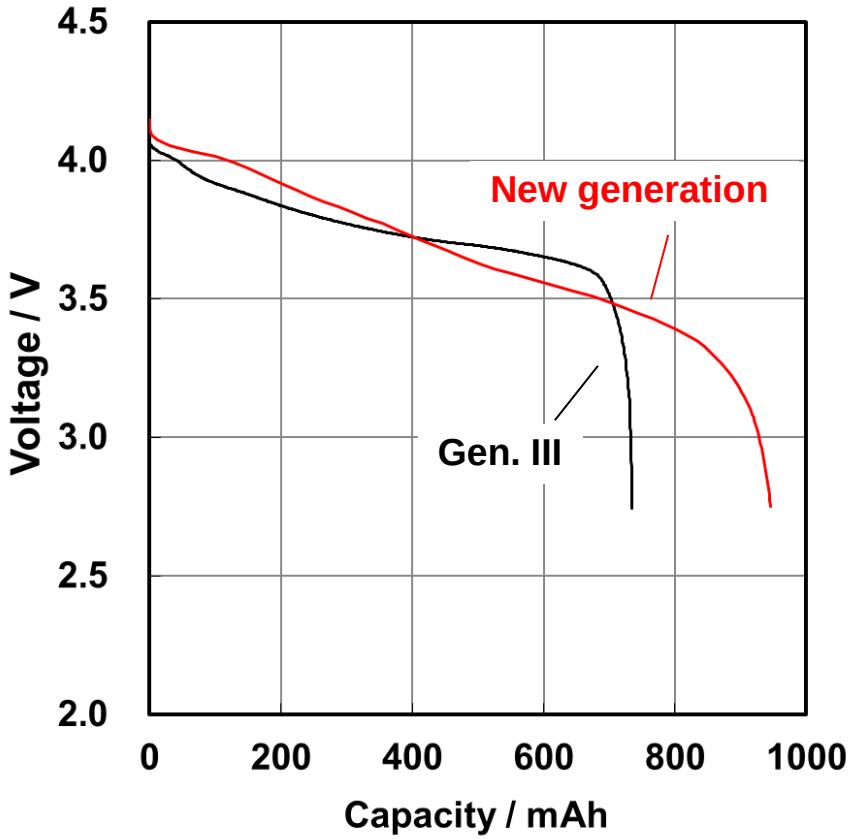
Roadmap for development of satellite cells

Target Specifications of new generation cells



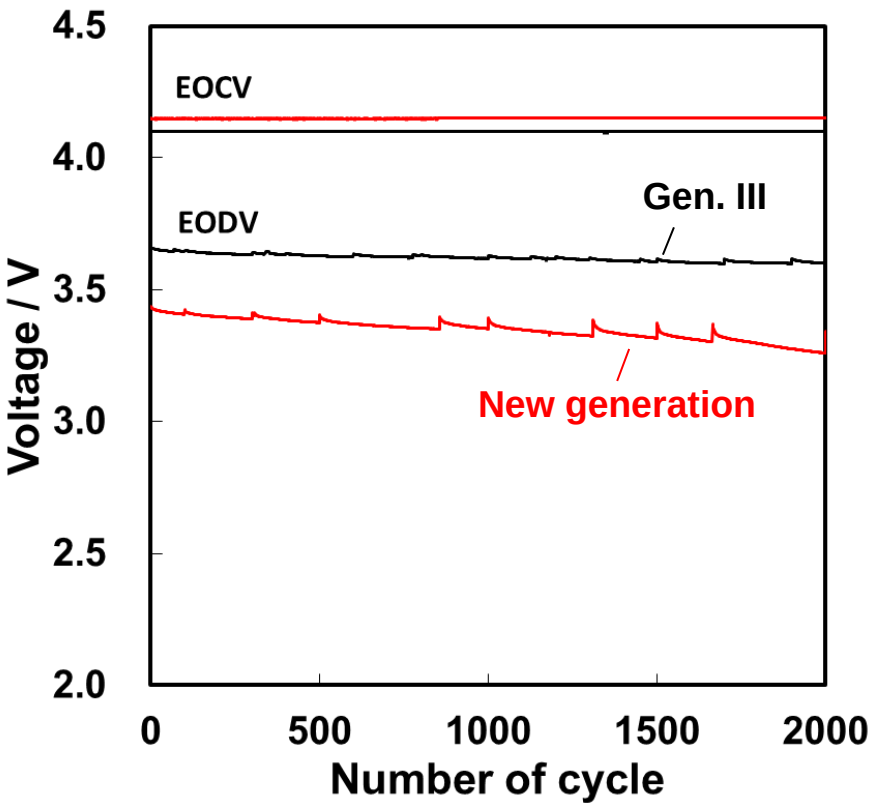
Items	New generation cells		Gen. III
	195 Ah size	250 Ah size	190 Ah size
Chemistry	NCM / Gr+SiO		LCO/Gr
Rated capacity / Ah	C/5 : 203 C/2 : 195	C/5 : 258 C/2 : 250	190
Actual capacity / Ah	C/5 : 225 C/2 : 217	C/5 : 287 C/2 : 277	205
EoCV/ V	4.15		4.10
Discharge Voltage / V	C/5 : 3.67 C/2 : 3.66		3.70
Mass / kg	3.56	4.66	4.59
Specific energy / Wh/kg	C/5 : 232 C/2 : 223	C/5 : 226 C/2 : 218	165

Discharge performance

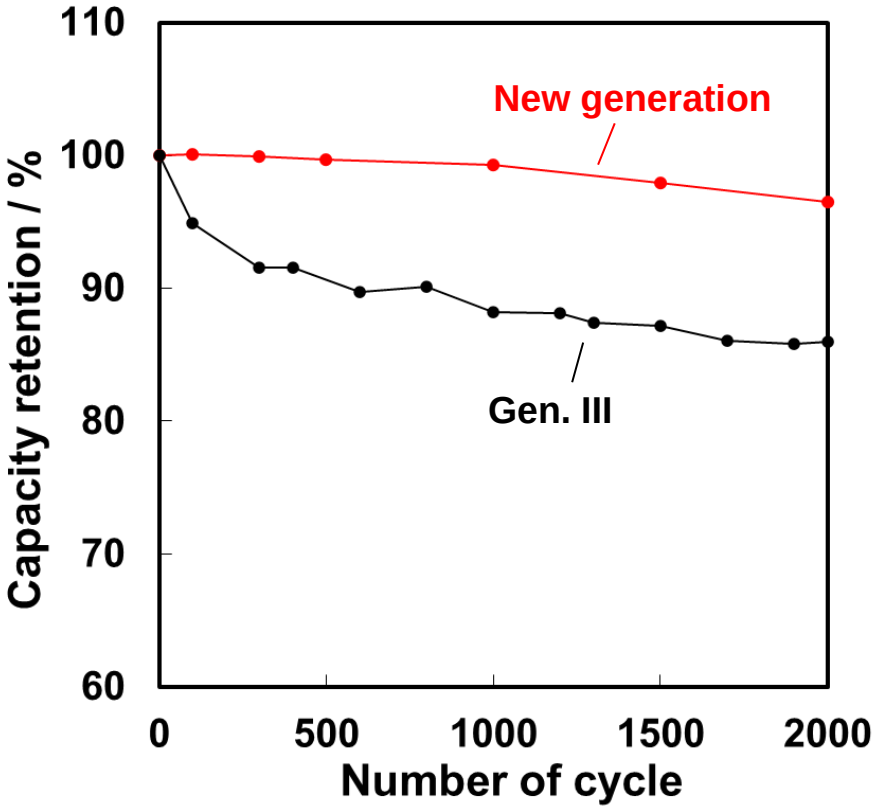


Discharge performance of 1 Ah class new generation cell

Accelerated GEO life performance



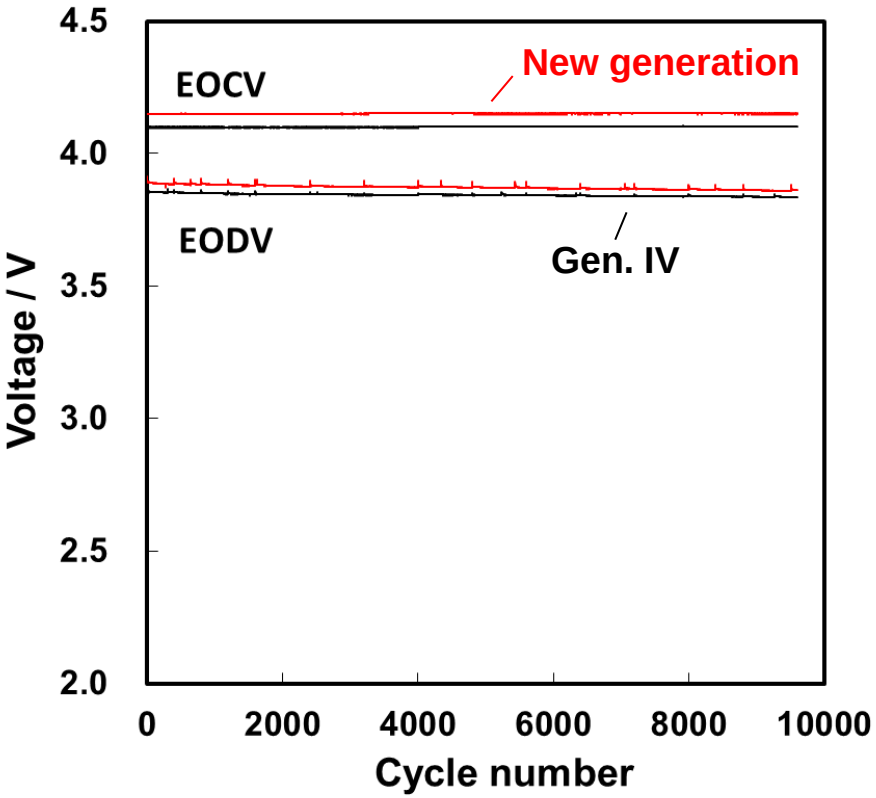
(a) EoCV/EoDV



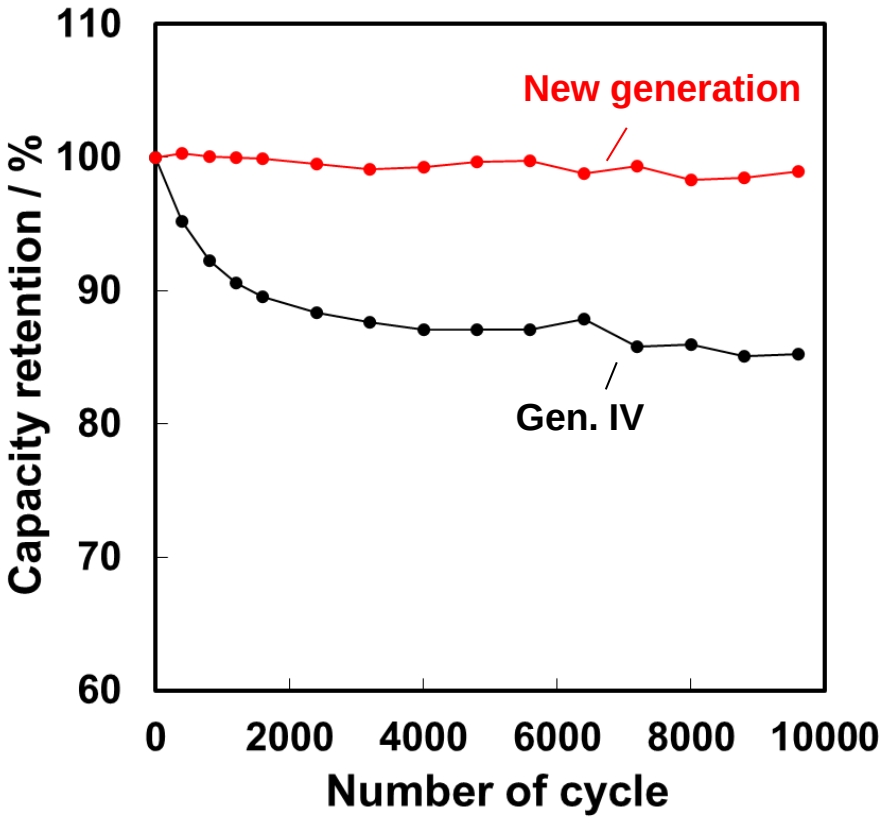
(b) Capacity retention

Continuous DOD 80% cycle life performance of 1 Ah class new generation cell

Realtime LEO cycle life performance



(a) EoCV/EoDV



(b) Capacity retention

Continuous DOD 25% cycle life performance of 1 Ah class new generation cell